PACIFIC NORTH WEST FOREST AND RANGE EXPERIMENT STATION

ALASKA OREGON WASHINGTON

· · USDA FOREST SERVICE RESEARCH NOTE

PNW-142 *February 1971*

SEQUENTIAL SAMPLING OF HEMLOCK SAWFLY EGGS IN SOUTHEAST ALASKA[1]

by

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ABSTRACT

Hemlock sawfly egg population concentrations are classified rapidly through examination of branch samples from the upper crowns of intermediate crown class western hemlock trees selected randomly in sequence. Branch samples are examined only until a single egg is found, which greatly reduces the amount of field time spent examining samples. A tree is called "infested" if the sample yields one or more eggs, and "uninfested" if the sample yields none. Percent of "infested" trees determines egg population concentration. The upper limit for an endemic to light population is 33.3 percent "infested" sample trees. The lower limit for a moderate to heavy population is 50.0 percent "infested" sample trees.

Keywords: *Neodiprion tsugae*, hemlock sawfly, sequential sampling, insect populations.

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[1] The Insect and Disease Control Section under D. Crosby, Region 10, provided funds and manpower for collection of data.

INTRODUCTION

The hemlock sawfly, *Neodiprion tsugae* Midd., is an important defoliator of western hemlock, *Tsuga heterophylla* (Raf.) Sarg., in southeast Alaska. Female sawflies oviposit by inserting eggs singly into the edges of western hemlock needles (fig. 1) in the fall. Usually several eggs comprising a clutch are laid in the needles of a single twig or adjacent twigs before a female moves to another oviposition site. After overwintering in the egg stage, larvae emerge in June. Therefore, the period from October to June provides opportunities for fall or spring sampling to estimate sawfly population levels.

Figure 1.--*Hemlock sawfly eggs in edges of western hemlock needles.*

In the past, population densities were estimated subjectively through a relatively crude system of larval or egg sampling. In order to quickly classify population densities with a known degree of confidence and to enable comparisons of densities between generations, the plan presented here was developed. Its primary purpose is to rapidly determine indices of egg population densities in southeast Alaska. These density classifications do not necessarily imply the same subsequent tree defoliation classifications. They do, however, show which areas could be defoliated significantly provided heavy mortality of young larvae does not occur. Since data for development of the plan were collected widely in southeast Alaska and from a variety of stand conditions, this plan can be used throughout the area.

MATERIALS AND METHODS

A total of 14 locations within nine sawfly infestations (fig. 2) were sampled during April and May of 1967 and 1968. In 1967, 18 hemlock trees were chosen randomly from three stand positions in each of seven infestations. These positions were (1) the fringe of the stand at tidewater, (2) inside the stand, and (3) upslope to the edge of the infestation or to the 500-foot elevation, whichever came first. At each of these three positions six trees were sampled--three intermediate crown class trees and three dominant or codominant crown class trees.[2/] The trees were felled, four 36-inch branch tips were removed from the whorl of branches nearest the midpoint of the upper crown half, and four were removed from the midwhorl of the lower crown half. Each branch was taken from a quadrant which contained one of the four cardinal directions when the tree was standing. If a single whorl did not represent all four cardinal directions, branches from adjacent whorls were collected to complete the sample. The branches were labeled and removed to the laboratory where each was divided into a 10-inch distal portion, an 18-inch distal portion, and the remainder. Foliar area and egg counts were recorded separately for each branch portion.

ANALYSIS

The 1967 data were analyzed to determine if significant differences in egg population densities occurred among the various strata. The only significant differences occurred between upper and lower crown levels in areas with high egg populations. Under these conditions, there were significantly more eggs in upper crown samples than in lower crown samples.

Analysis of 1967 data showed a highly significant correlation coefficient of 0.918 between mean numbers of eggs per square foot of foliage from all sampling strata and mean numbers of eggs per 18-inch branch from all trees except those on the fringe at tidewater. Therefore, in 1968, only 12 trees were sampled in each of seven areas (fringe trees were not sampled) and only 18-inch branches were collected for subsequent egg counts. Measurement of foliar area was considered unnecessary because of the strong correlation between egg counts based on foliar area and egg counts per 18-inch branch. Fringe trees were eliminated from the sample because they make up only a small portion of the stand, because their crowns are atypical of crowns within

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[2/] *Intermediate*--trees with crowns receiving light from above; tops of crowns generally below level of crown cover but not overtopped.

Codominant--trees with crowns receiving light from above and partially from the sides; tops of crowns composing the general level of crown cover.

Dominant--trees with crowns receiving light from above and from the sides; tops of crowns usually above level of crown cover.

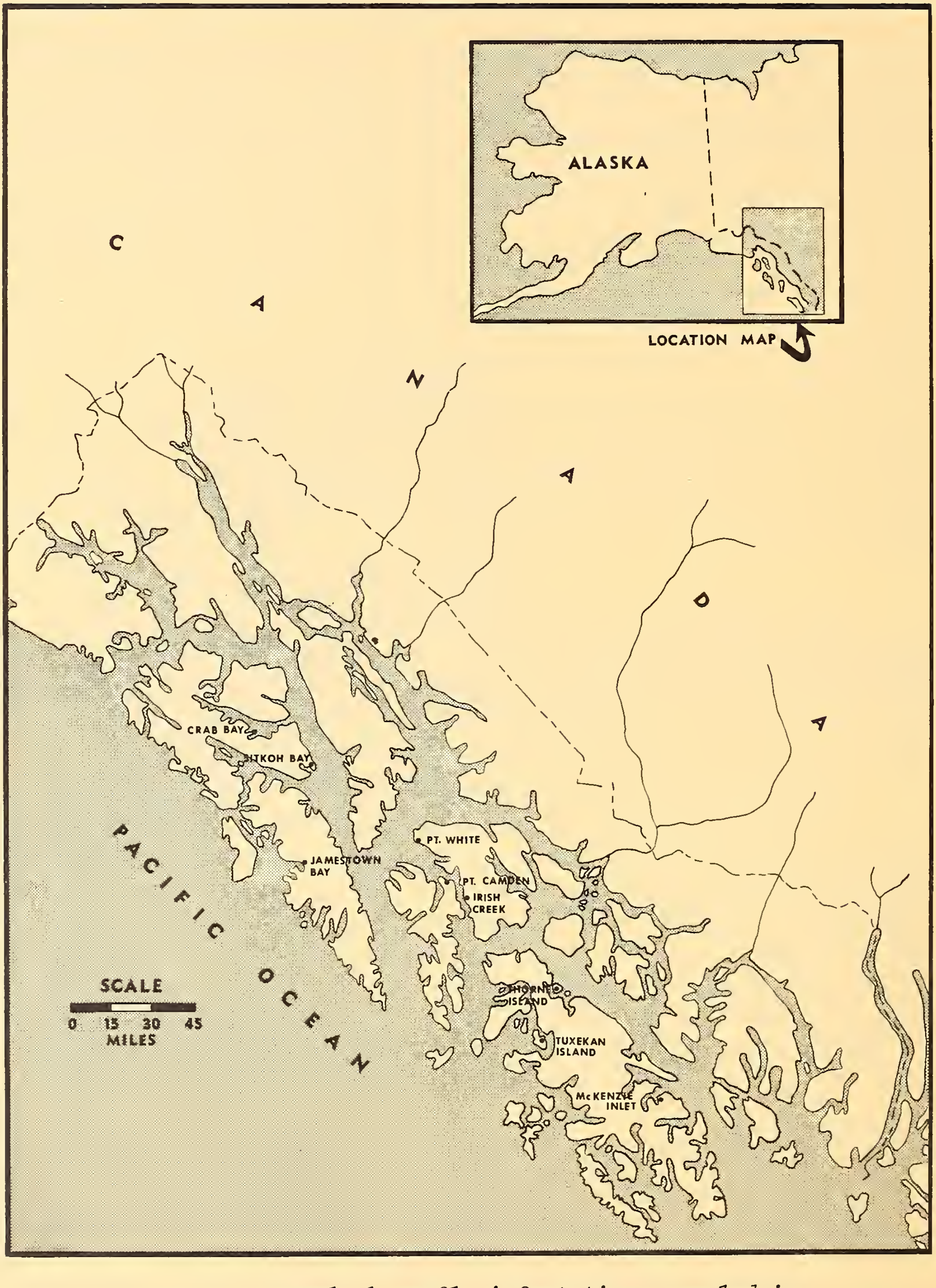

Figure 2.--*Hemlock sawfly infestations sampled in southeast Alaska, 1967 and 1968.*

the stand, and because edge effect and beach-logging of Sitka spruce, *Picea sitchensis* (Bong.) Carr., in the past has resulted in atypical stand composition within fringe areas.

Combined data of 1967 and 1968 showed a highly significant correlation of 0.788 between mean number of eggs per 18-inch branch from all strata and percent of trees that had one or more eggs on upper and lower crown samples. Further analysis showed a highly significant correlation of 0.862 between mean number of eggs per 18-inch branch from all sample strata and percent of intermediate crown class trees only, whose upper crown samples had one or more eggs.

Because egg counting is difficult and time consuming, it was felt that percent of infested trees would give a more rapid estimate of population index. Upper crowns of intermediate crown class trees were chosen as the tree portion to sample because they are not defoliated as heavily as upper crowns of dominant and codominant trees during high population levels, and their egg populations are more closely correlated with overall egg populations within the stands. In addition they are easier to sample and, if felled, result in minimal loss to the stand.

THE SEQUENTIAL PLAN

Many sequential sampling plans use cumulative numbers of insect adults, pupae, larvae, or eggs in making population-index decisions.[3/] This plan uses cumulative number of infested trees. It has a major advantage in ease of application over the conventional system in that branch sample units from a single tree are examined only until a single egg is found, and the remainder of the sample is discarded. This saves much time and eliminates the need for making accurate egg counts under the relatively dark, wet conditions that commonly occur in the field in fall and spring.

Class limits for this plan are as follows:

> *Zero to light population.*--Of the sample trees on a plot,[4/] 33.3 percent or less bear one or more eggs, which corresponds with an egg population mean of

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[3/] W. E. Waters. Sequential sampling in forest insect surveys. Forest Sci. 1: 68-79. 1955.

[4/] A plot consists of a sequential sample of trees from which a single egg population-index decision is made.

approximately two eggs or fewer per 18-inch branch sample from upper and lower crowns of dominant, codominant, and intermediate crown class trees.

Moderate to heavy population.--Of the sample trees on a plot, 50.0 percent or more bear one or more eggs, which corresponds with an egg population mean of approximately five eggs or more per 18-inch branch sample from upper and lower crowns of dominant, codominant and intermediate crown class trees.

These classes may appear conservative on a mean egg-number-per-branch basis, but the means for upper crowns, where population densities are greatest, are considerably higher than the combined means for upper and lower crown levels shown above.

USE OF THE PLAN

A starting point is chosen at random within a known or suspected sawfly infestation. A die is thrown to determine which direction the sampler will travel to the initial sample point. One represents a 60-degree azimuth; two, 120 degrees; three, 180 degrees; etc. The die is thrown a second time to determine the distance in chains the sampler will travel along the predetermined azimuth. One represents 1 chain, two represents 2 chains, etc.

When the initial sampling point is reached, the nearest intermediate crown class western hemlock tree is climbed or felled, and a sample composed of four 18-inch branch tips is removed from the approximate midpoint of the upper crown. The sample is examined until an egg[5/] is found and then the sample is discarded. The information is recorded on the sampling form (fig. 3). Beginning at the origin of the sequential sampling graph, a line is drawn up one square for an infested tree or right one square for a noninfested tree. The die is thrown again to determine the azimuth and distance to the next sample tree, where the sampling procedure is repeated. Sampling is continued until the penciled trace on the graph crosses one of the decision lines. Using a 10-percent α or β error level, 11 trees were sampled before a "moderate to heavy population" decision was made on the sample form (fig. 3).

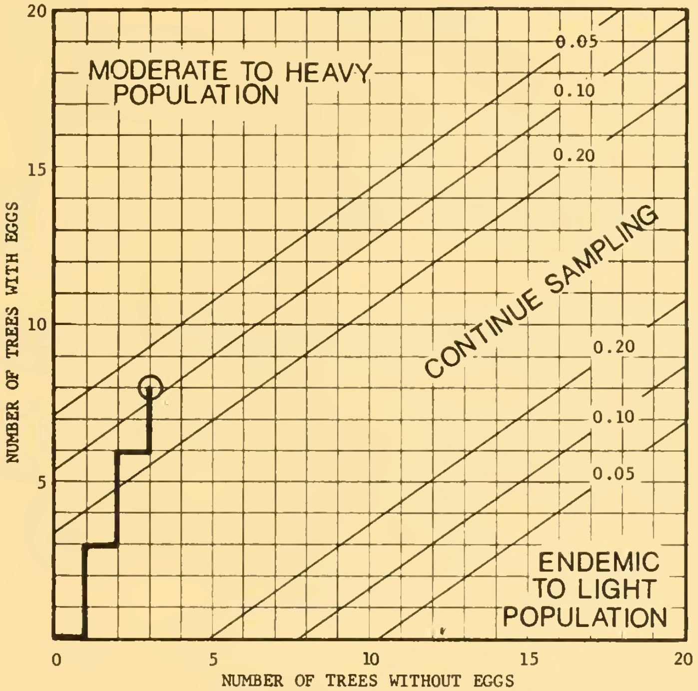
5/ Only eggs laid by females of the most recent generation are to be considered. Although eggs from the penultimate generation may still be found, they can usually be identified by the brown, damaged needle tissue surrounding them and age of needles on which they occur. The sawfly prefers current year's needles for oviposition.

HEMLOCK SAWFLY SEQUENTIAL EGG SAMPLING FORM

Date: Nov. 10, 1969 Hard and Curtis

Location of Sampling Area: McKenzie Inlet, South Tongass National Forest

Plot Location: West Side, Peacock Island



TREE NO.	AZIMUTH (degrees)	DISTANCE (chains)	DBH (inches)	HEIGHT (feet)	CROWN DEFOLIATION (25% increm.)	NO. SAMPLE BR. DEFOL. (0 to 4)	EGGS PRESENT (yes or no)
1	120	3	14	—	< 25	0	No
2	60	1	16	—	50	2	Yes
3	60	4	16	—	75	4	Yes
4	180	3	18	—	> 75	4	Yes
5	120	2	22	—	25	1	No
6	360	5	12	—	50	3	Yes
7	60	6	16	—	> 50	2	Yes
8	300	6	18	—	75	4	Yes
9	300	1	24	—	> 50	0	No
10	180	5	16	—	< 50	2	Yes
11	120	4	14	—	< 50	2	Yes
12							
13							
14							
15							
16							
17							
18							
19							
20							

Figure 3.--*Hemlock sawfly egg sequential sampling form.*

If the trace had not crossed a decision line, sampling would have been discontinued at 15 trees and the plot called a borderline case. The decision lines are calculated according to specifications given by Dixon and Massey.[6] This equation was used:

$$Y = \frac{\pm Ln\left[\frac{1-\beta}{\alpha}\right] - Ln\left[\frac{1-P_l}{1-P_o}\right] X}{Ln\left(\frac{P_l}{P_o}\right)}.$$

where

Y = number of infested trees

X = number of noninfested trees

Ln = natural logarithm

P_o = upper limit to the proportion of infested trees in the infestation class called zero to light (e.g., P_o = 33 percent).

P_l = lower limit to the proportion of infested trees in the infestation class called moderate to heavy (e.g., P_l = 50 percent).

α = probability of calling the population moderate to heavy when the actual proportion of infested trees is P_o (e.g., α = 10 percent).

β = probability of calling the population zero to light when the actual proportion of infested trees is P_l (e.g., β = 10 percent).

Choice of a decision line probability level is made before sampling is begun. The inner decision lines[7] in figure 3 are the least precise since they can be expected to give an incorrect decision one out of five times, but the number of sample trees required is minimal. The outer decision lines[8] are the most precise since they can be expected to give an incorrect decision only one out of 20 times, but the number of sample trees required is greatly increased. The intermediate decision lines,[9] which can be expected to give an incorrect decision one out of 10 times, are adequate for most sampling.

6/ Wilfred J. Dixon and Frank J. Massey, Jr. Introduction to statistical analysis. 2d ed. New York, McGraw-Hill, Inc., 1957.

7/ $\alpha = \beta = 20$ percent. $Y = \pm\ 3.42 + 0.71X$.

8/ $\alpha = \beta = 5$ percent. $Y = \pm\ 7.25 + 0.71X$.

9/ $\alpha = \beta = 10$ percent. $Y = \pm\ 5.42 + 0.71X$.

Although the graph is essentially a two-level classification, it can be further exploited, as follows: If none of the sample trees bear eggs, the penciled trace on the graph follows the horizontal axis and indicates an endemic population. If all of the sample trees bear eggs, the penciled trace on the graph follows the vertical axis and indicates a heavy population.

Unless the area of the infestation being sampled is relatively small, a single plot will not give an index of population for the entire area. Therefore, an infestation should be broken down into several areas, perhaps determined by degree of defoliation, and one or more sequential samples or plots taken in each. The number of sequential samples taken in an infestation is determined by the sampler's concern for a particular infested stand. The population index for an entire infestation is merely a compilation of the various sample decisions made within the infestation and is represented by the percent of sample plots falling within each class.

Although the data on which this sampling plan is based were gathered in the spring after overwintering egg loss had occurred, the plan can also be used in the fall because overwintering egg loss rarely, if ever, results in loss of an entire egg clutch. Since spring sampling gives little leadtime if results of the sample indicate that control action should be taken in an infestation, fall sampling may be justified in some cases.

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2. Development and evaluation of alternative methods and levels of resource management.
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